Observations on three-dimensional measurement of confined fission track lengths in apatite using digital imagery

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ABSTRACT

We report the results of a comparative study to explore the usefulness of 3D measurements of confined fission track lengths (TINTs) relative to horizontal confined track length measurements (dips ≤10°), and evaluate their suitability for thermal history modeling. Confined fission track lengths were measured in 10 annealed Fish Canyon Tuff apatites containing synthetic mixtures of different length components, and two Durango apatites containing spontaneous fission tracks. Measurements were primarily carried out using a digital image-based microscope system, and they were compared to those from a regular optical drawing tube-digitizing tablet setup, and a confocal laser scanning microscope. The results indicate that 3D measurements of confined track lengths are closely comparable to conventional horizontal track measurements, and the mean track lengths of inclined (dips >10°) and horizontal (dips ≤10°) confined tracks from the one sample are equivalent within the measurement uncertainty. A strong dip-bias was observed, so that almost all the confined tracks measured were dipping at <30°, and the great majority (~70%) were dipping at ≤10°, thereby qualifying as “horizontal” confined tracks. Our results suggest that a useful increase of more than 40% in sample size can be achieved from including dip- and refraction-corrected 3D track length measurements. Some evidence was seen for a small bias in favor of shorter tracks at higher dip angles but this has very little influence on the mean lengths or length distributions up to the practical limit of dips (~30°) observed in these measurements. Results obtained using the same measurement system by a single analyst over time and between six different observers in the one laboratory show good reproducibility. These results also agree well with conventional horizontal confined track length measurements in the same samples in the second laboratory involved. We conclude that 3D measurements of confined track lengths, including both horizontal and inclined tracks, are suitable for use in current fission track annealing models derived from experiments using horizontal confined tracks.

Keywords: Thermochronology, fission track dating, apatite, confined track lengths, 3D measurement, digital imaging

INTRODUCTION

Apatite fission track (AFT) thermochronology is used for reconstructing geological thermal histories through combining apparent age and confined track length measurements (e.g., Gleadow et al. 2002; Gallagher 2012; Ketcham 2005). Fission tracks form continually over time, but the length of each track is subjected only to the subsequent thermal history since its formation. Thus, the distribution of confined track lengths in a particular sample is characteristic of its thermal history (Gleadow et al. 1986) since entering the partial annealing zone. Detailed thermal histories can be reconstructed from the combined fission track length and age data by using fission track annealing models (e.g., Ketcham et al. 1999; Laslett and Galbraith 1996; Laslett et al. 1987).

Laslett et al. (1982) pointed out that all practical schemes for sampling etched fission track lengths will be subject to various kinds of bias. They concluded that sampling horizontal confined fission tracks will be the least biased and provide the closest approximation to the underlying distribution of unetched track lengths. Since that work, and later empirical studies by Gleadow et al. (1986), standard practice has been to measure the projected lengths of such horizontal confined track (HCTs). In reality, “horizontal” is taken to mean tracks dipping at up to ~10° (Donelick et al. 2005) or even ~15° (Laslett et al. 1982), for which the resulting errors introduced by measuring only the horizontal length component are relatively small, ~1.5 to ~3.4%, respectively.

In the absence of actual dip measurements, it is obviously difficult to apply these criteria for a particular track to be horizontal in any rigorous sense. Mostly the operator makes a qualitative judgment based on the focus and appearance of the track in transmitted and/or reflected light, which will therefore depend